PRESENT-DAY MASS BALANCE OF WEST AND EAST ANTARCTIC GLACIERS.

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INTRODUCTION

• The scientific of this study is to reduce uncertainties in estimates of the current mass budget of the Antarctic ice sheet.

• As most of the discharge of ice from the continent is controlled by a few large glacier systems, a good indication of the state of mass balance of the ice sheet is to examine whether those glaciers are discharging more or less ice than accumulates in the interior through snow accumulation and wind-driven redistribution.

• SAR interferometry and radar altimetry have produced important new data sets to help us reduce those uncertainties significantly:

* a continuous topographic coverage of the continent, at low resolution (5km), including all ice shelves to provide improved estimates of drainage basins and ice thickness proxy on floating ice.

* measurements of glacier velocities, in two dimensions (from crossing tracks, or from a combination interferometry/speckle tracking); and precise location of the grounding line of the glaciers.

• Over a shorter time-scale, limited by the availability of SAR data, a more precise determination of the glacier mass balance is to detect the migration of their grounding line. Only portions of West Antarctica have been covered on multiple years.

METHODS

- Ice velocity measured in vector form from a combination of ascending and descending tracks of the satellite (West Antarctica) or from descending tracks coupled with speckle tracking.

- The hinge line position is located precisely from quadruple difference interferometry data. An heuristic rule is used to determine where the line of first hydrostatic equilibrium is located compared to the hinge line: one fringe spacing from the first tidal fringe (this is based on Greenland results).

- Balance discharge is computed from Giovinetto and others, 1997.

- The grounding line of West Antarctic glaciers was mapped repeatedly in 1992 (1994) and 1996. Surface slope and bedrock slopes are required to convert the detected levels of migration into an ice thinning/thickening rate. Tidal effects have to be accounted for.

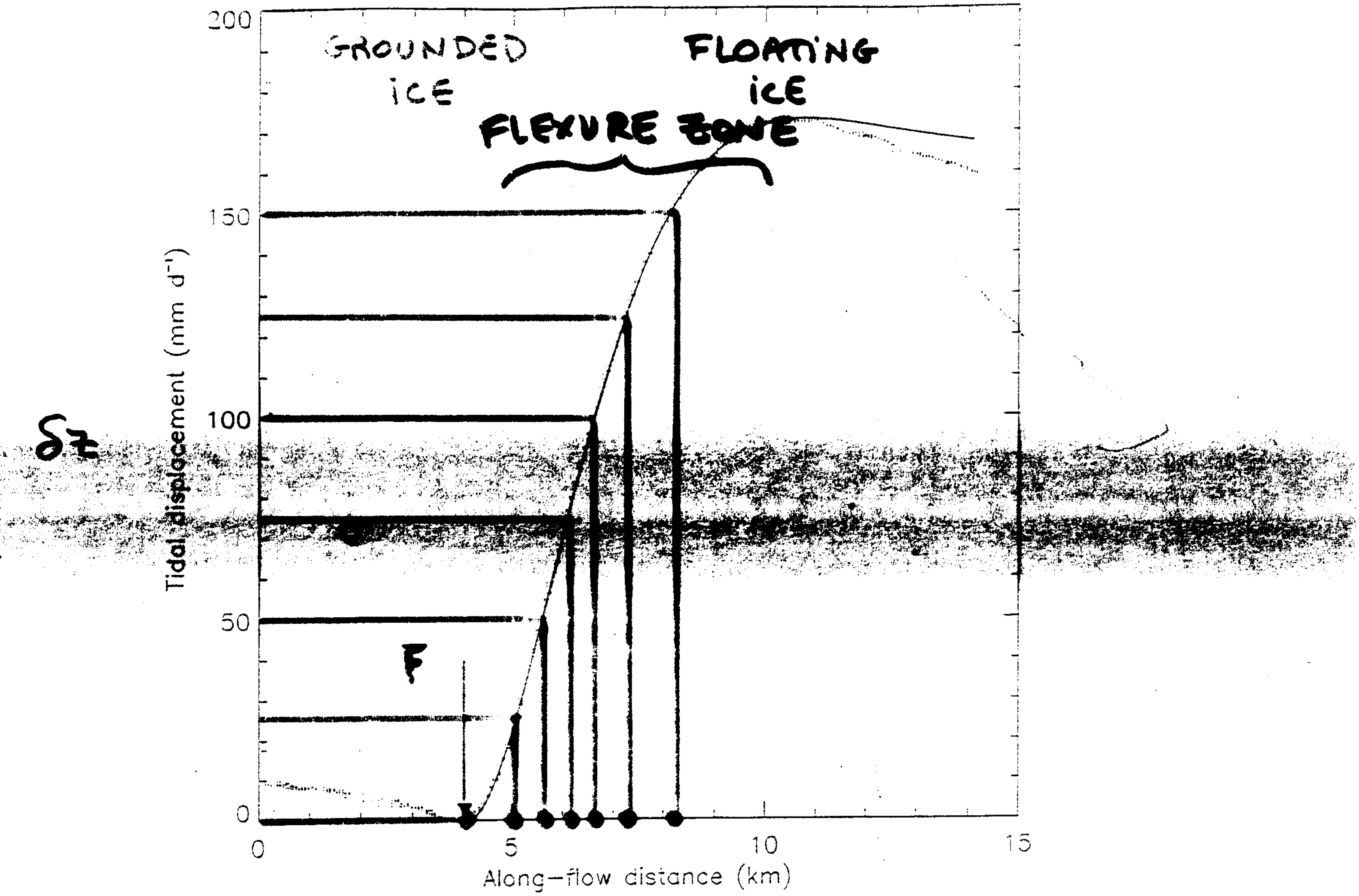
- By measuring the ice discharge downstream of the grounding line and assuming that the ice shelves are in a state of mass balance with negligible ablation/accumulation, we obtain indirect estimates of basal melting.

Table 1. **RESULTS**

West and East Antarctic Glaciers surveyed with ERS SAR and altimetry.

W = width at grounding line in km;
V = center velocity at grounding line in m a^{-1},
T = center thickness at grounding line in m;
GF = grounding line flux in km^3 ice a^{-1};
ACC = total accumulation above grounding line in km^3 ice a^{-1};
MB = mass balance in km^3 ice a^{-1} = ACC - GF;
BM = basal melting of first 20 km in m a^{-1};
δX = retreating rate of the grounding line in m a^{-1}.

Glacier	W	V	T	GF	ACC	MB	BM	δX
Rutford Ice Stream	20	390	2000	17.6	17.7	0.	10.6	0
Carlson Inlet	15	110	2100	2.9	2.9	0.	2.4	-100
Evans Ice Stream	40	750	1500	50.6	44.2	-6.4	5.2	NA
Eltanin Bay	20	400	1200					NA
Pine Island Glacier	25	2000	1300	76.1	70.8	-5.8	58.0	-1200
Thwaites Glacier	50	2000	1300	80.4	58.6	-21.8	35.0	-350
Land Glacier	15	400	1200					NA
David Glacier	15	500	1000	13.6	13.6	0.		NA
Nimitz Glacier	25	500	1200					NA
Totten Glacier	40	500	1500	69.3	61.2	-8.1		NA
Denman Glacier	20	600	1200	25.0	25.0	0.		NA
Lambert Glacier	40	700	1800	48.0	47.8	0.		NA



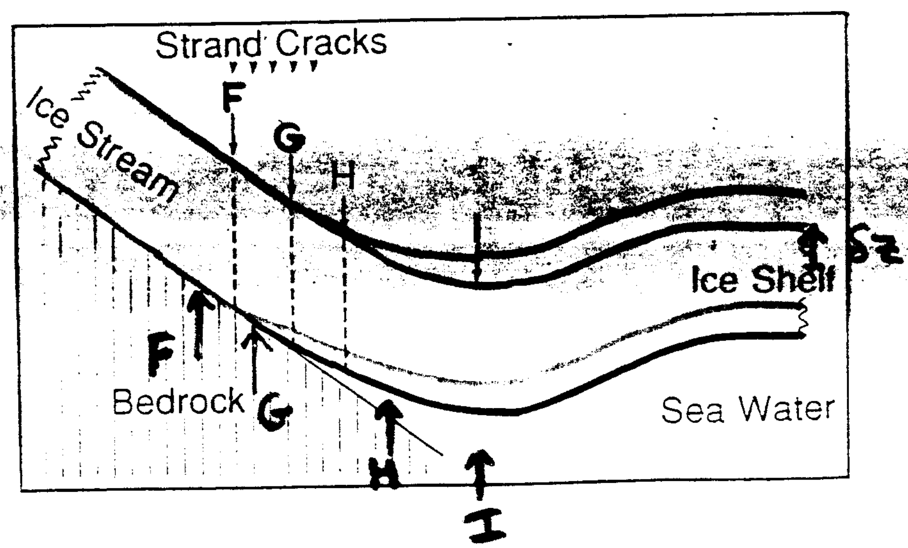
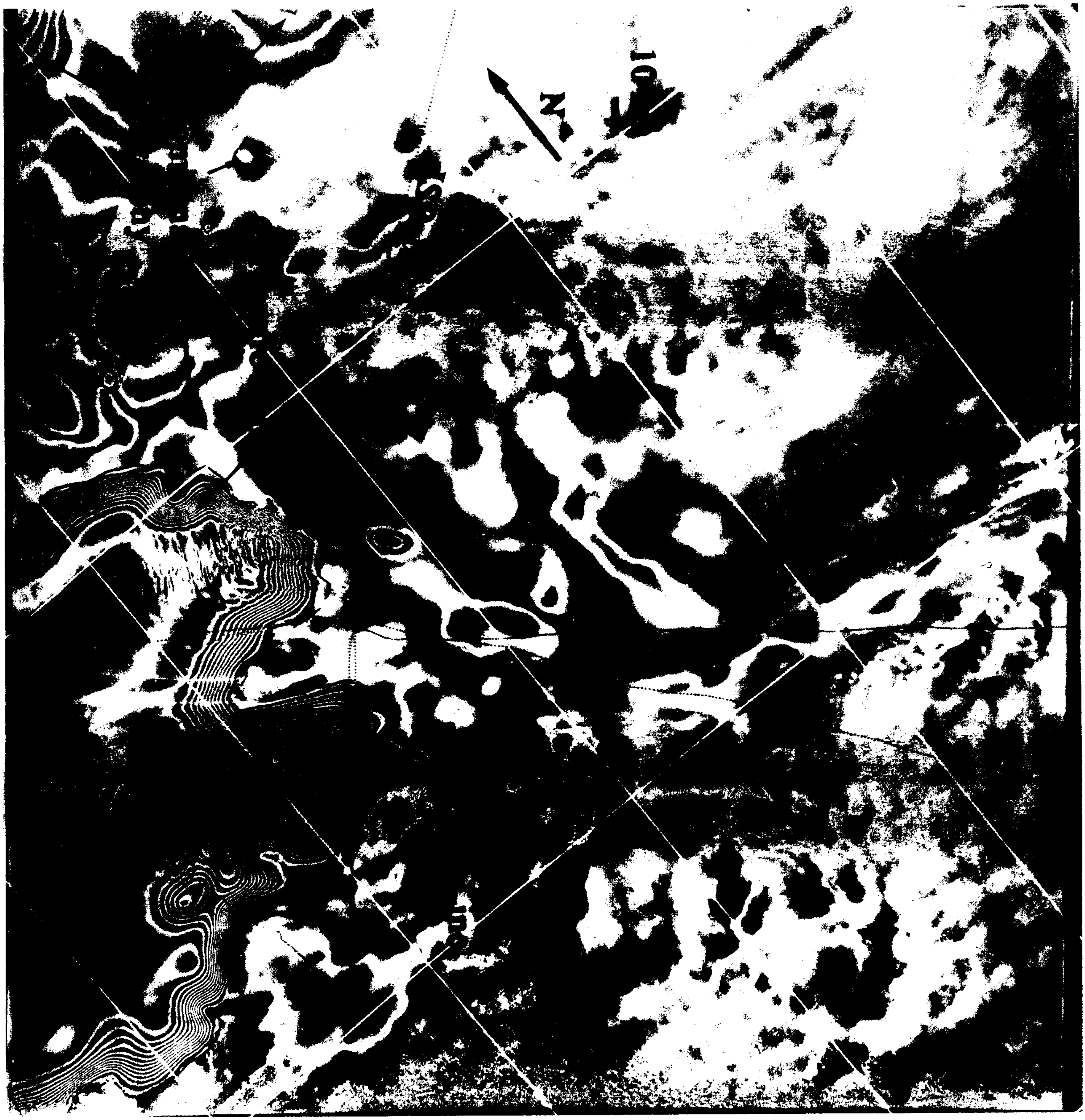


Fig. 1. Schematic grounding zone showing, the limit of flexure (F), the grounding line (G), the hydrostatic point (H), the point of gradient change (I) and the region over which strand cracks may be expected. After Smith (1991) and expected for Rutford Ice Stream.

Vaughan, 1994


N
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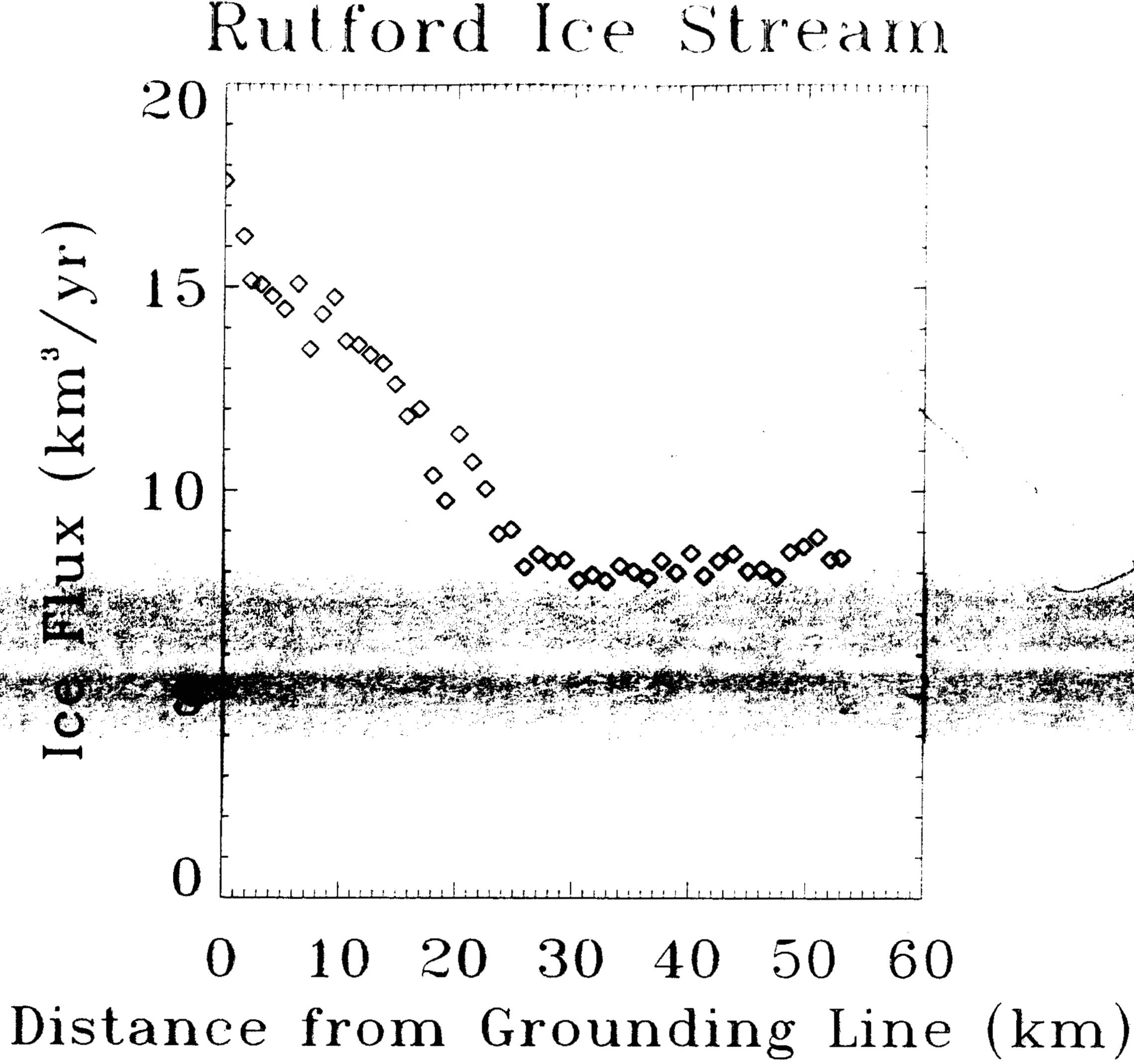
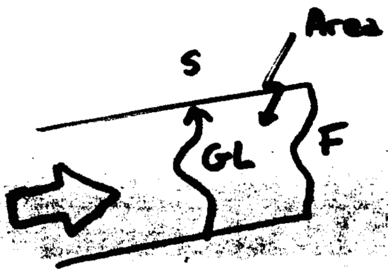


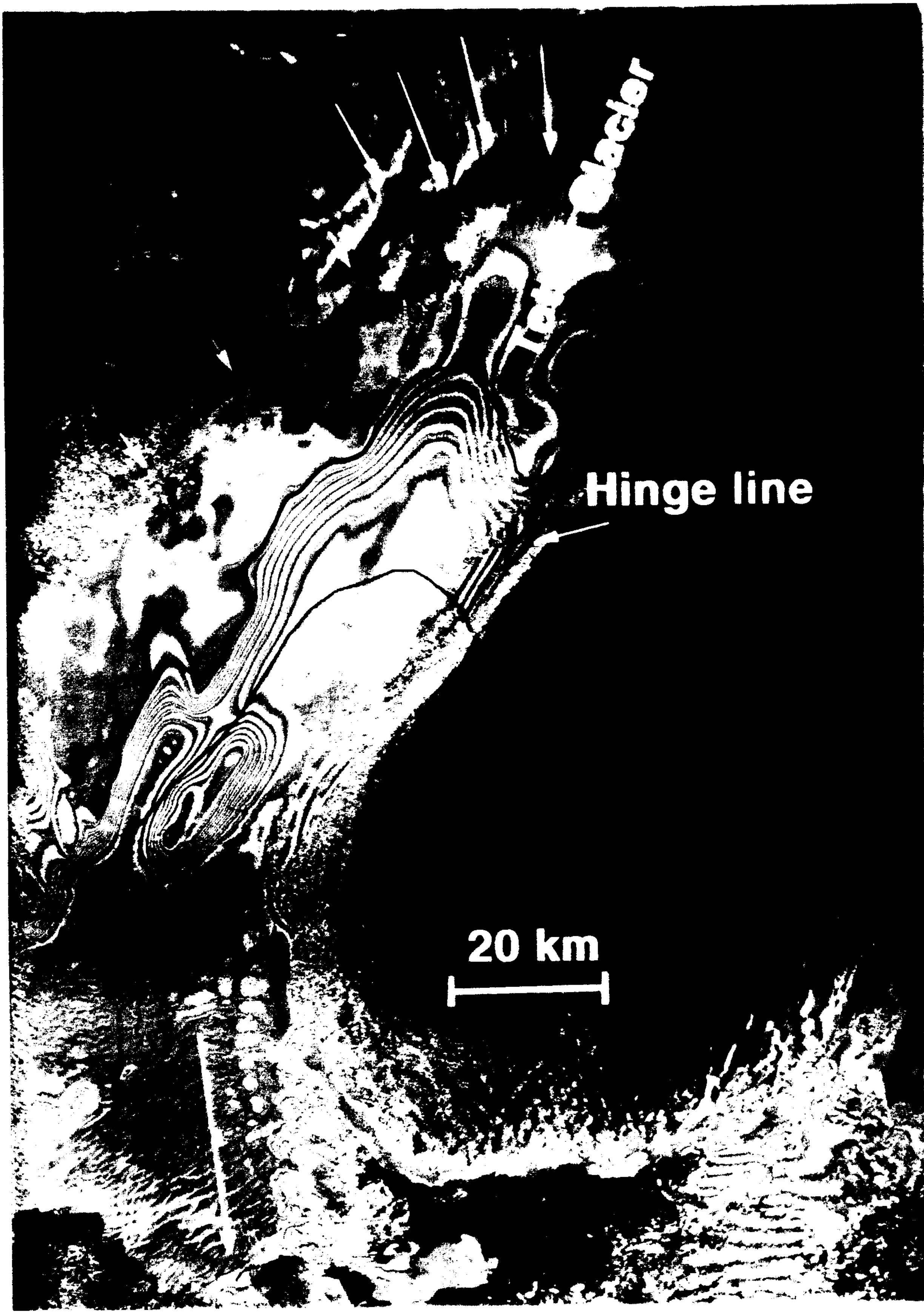


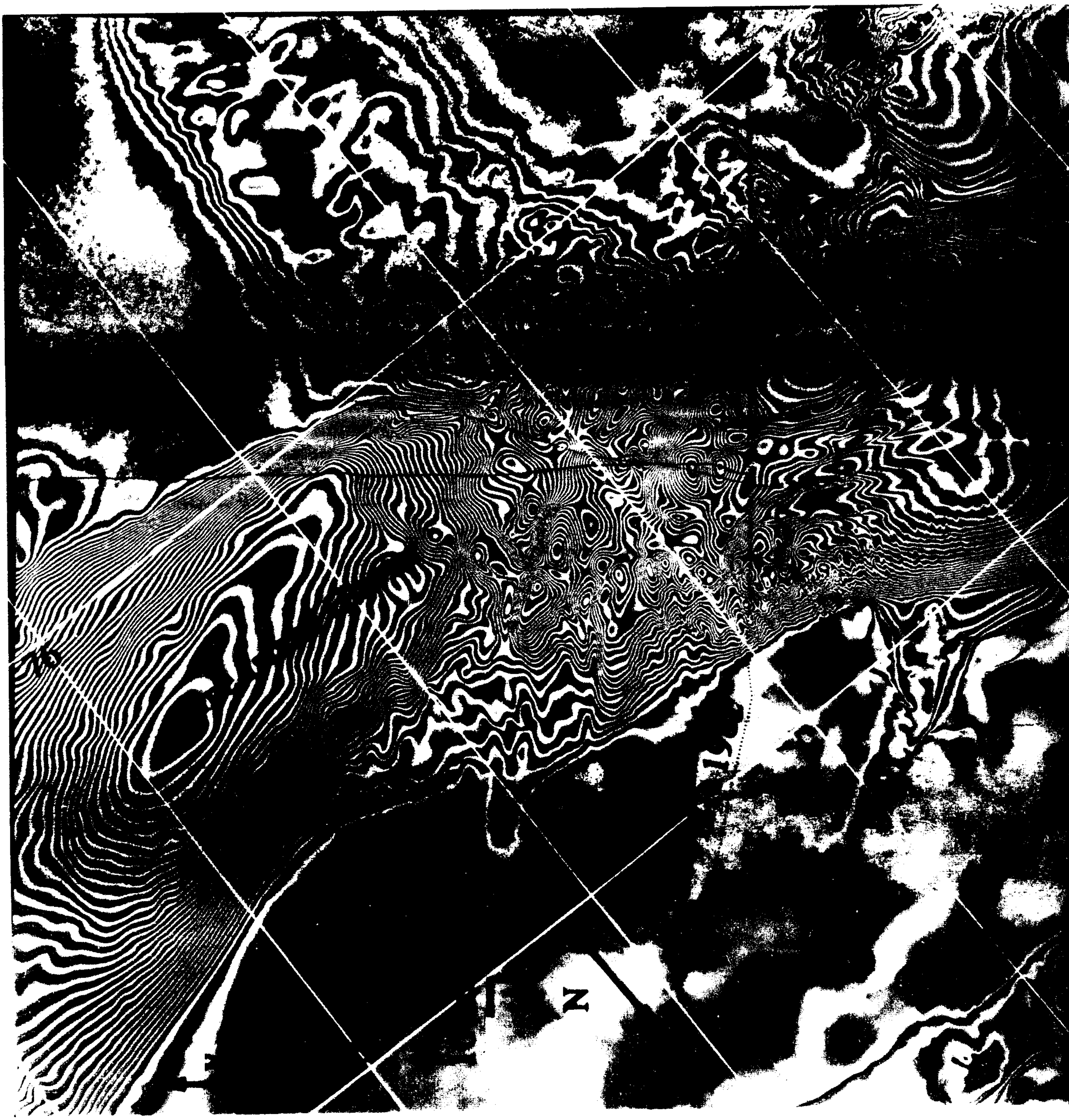
$$\Phi_{GL} = \int_{GL} h(s)\, \vec{V}_s \cdot \vec{n}_s \, ds \quad \text{km}^3 \text{ ice/yr}$$

$$\dot{B} = \frac{\Phi_{GL} - \Phi_F}{\text{Area}} \quad \text{m ice/yr.}$$

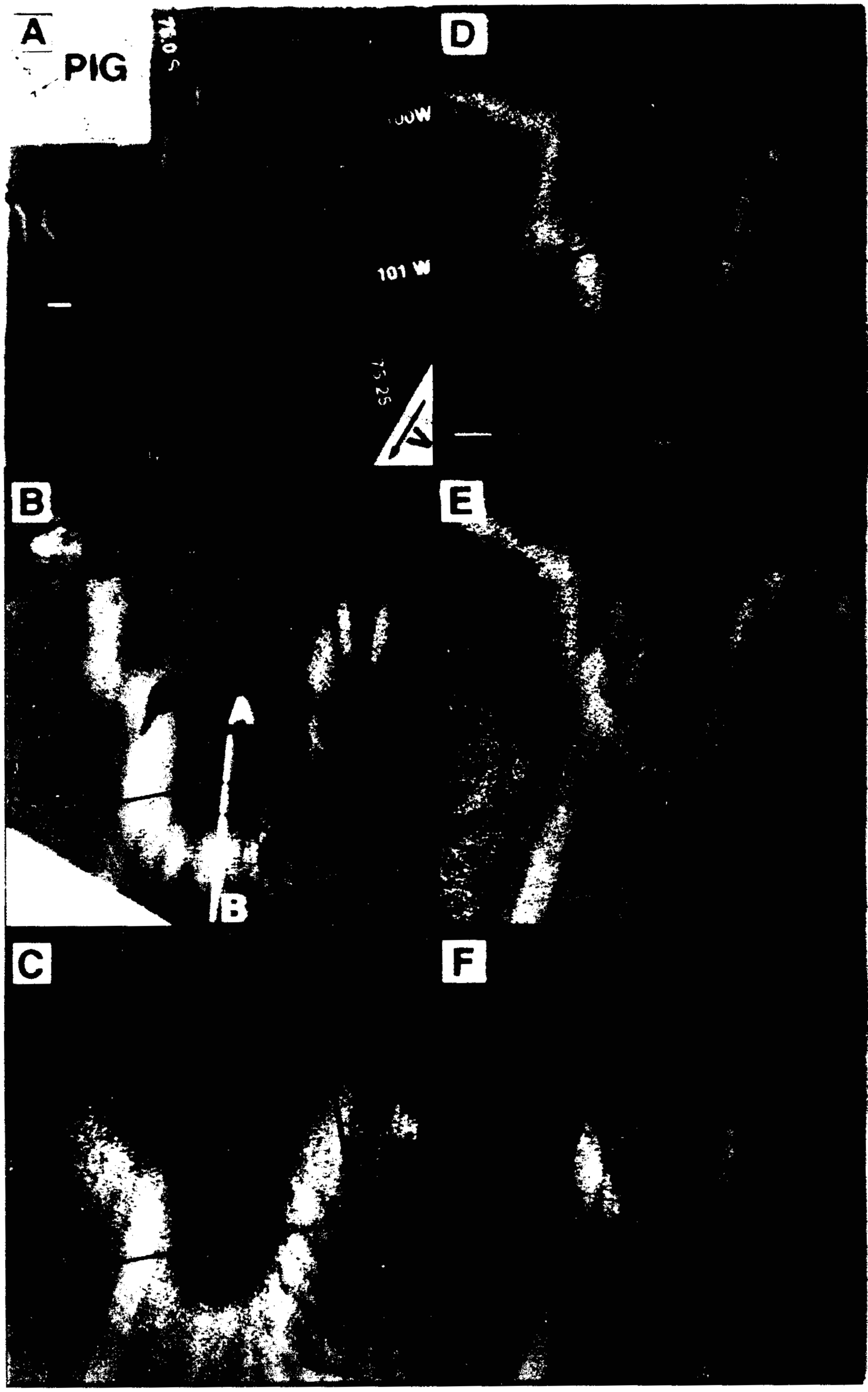
Rutford Ice Stream: $\Phi_{GL} = 17.6 \text{ km}^3/\text{yr}$

$\dot{B}_{20\text{-km}} \sim 11.6 \text{ m/yr}$

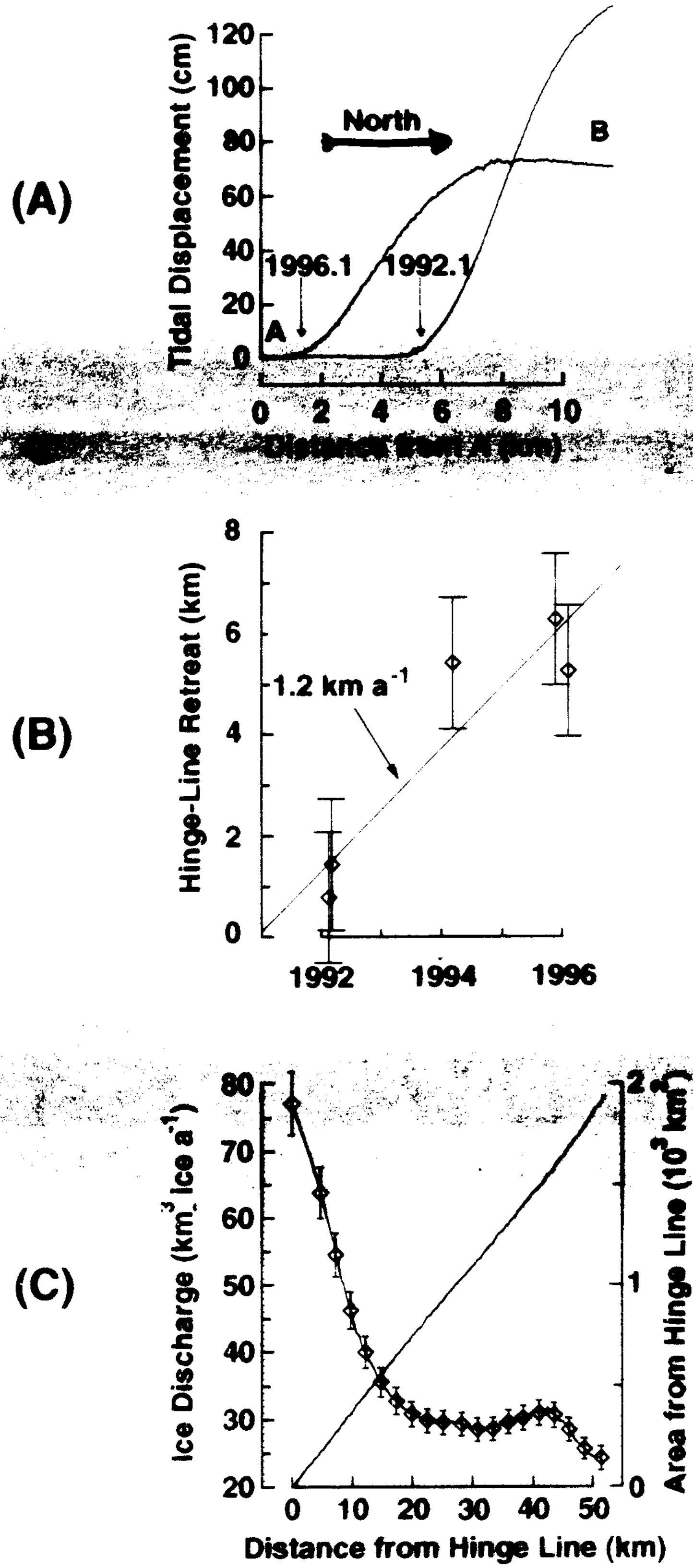

Glacier
Hinge line
20 km



Fast Recession of a West Antarctic Glacier



E. Rignot, JPL
Science 281, 549, 1998



1.2 km a^{-1} retreat

↓

3.5 m a^{-1} thinnin
at GL.

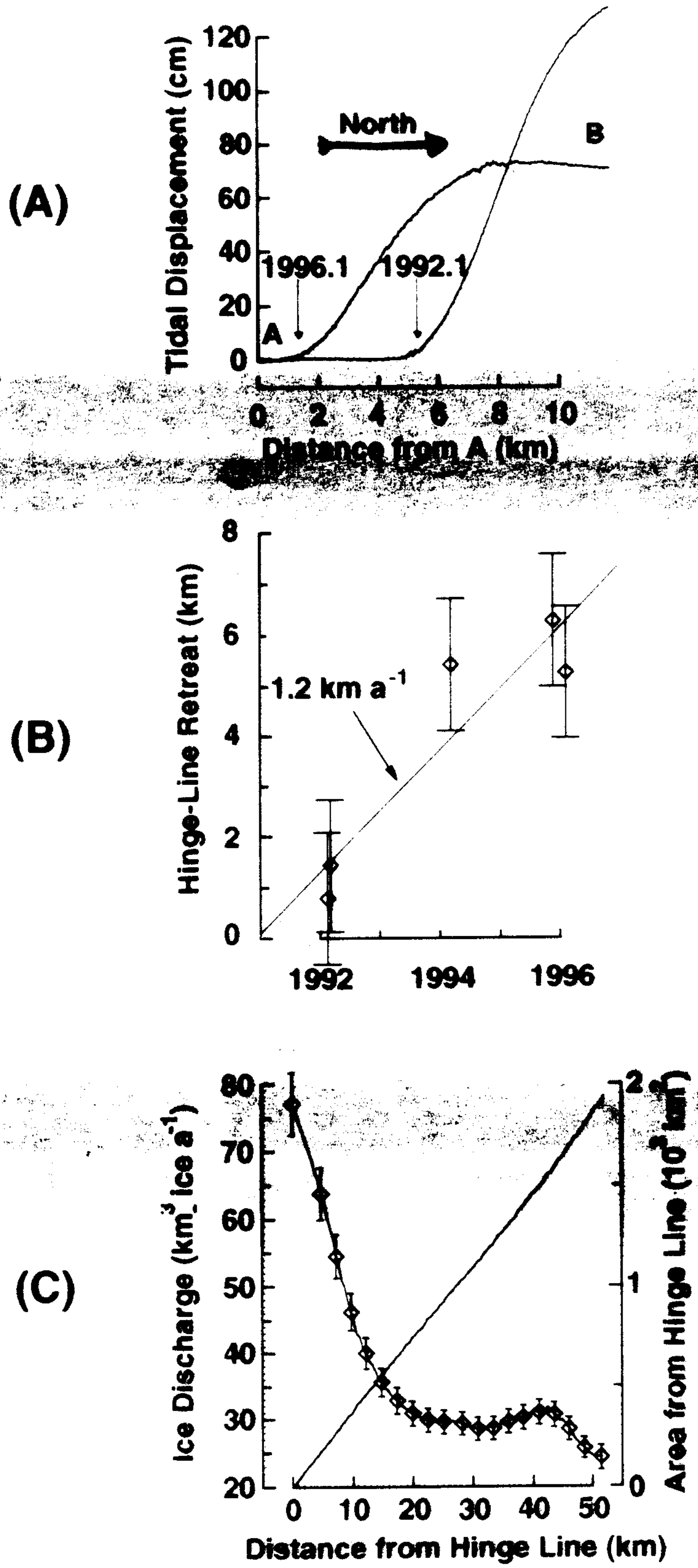
$\Phi_B \sim 70.8$ km^3 a^{-1}

$\Phi_{GL} \sim 76.1$ km^3 a^{-1}

$\bar{B} \sim 24$ m a^{-1}

$B_{GL} \sim 58$ m a^{-1}

Fig. 2, Rignot



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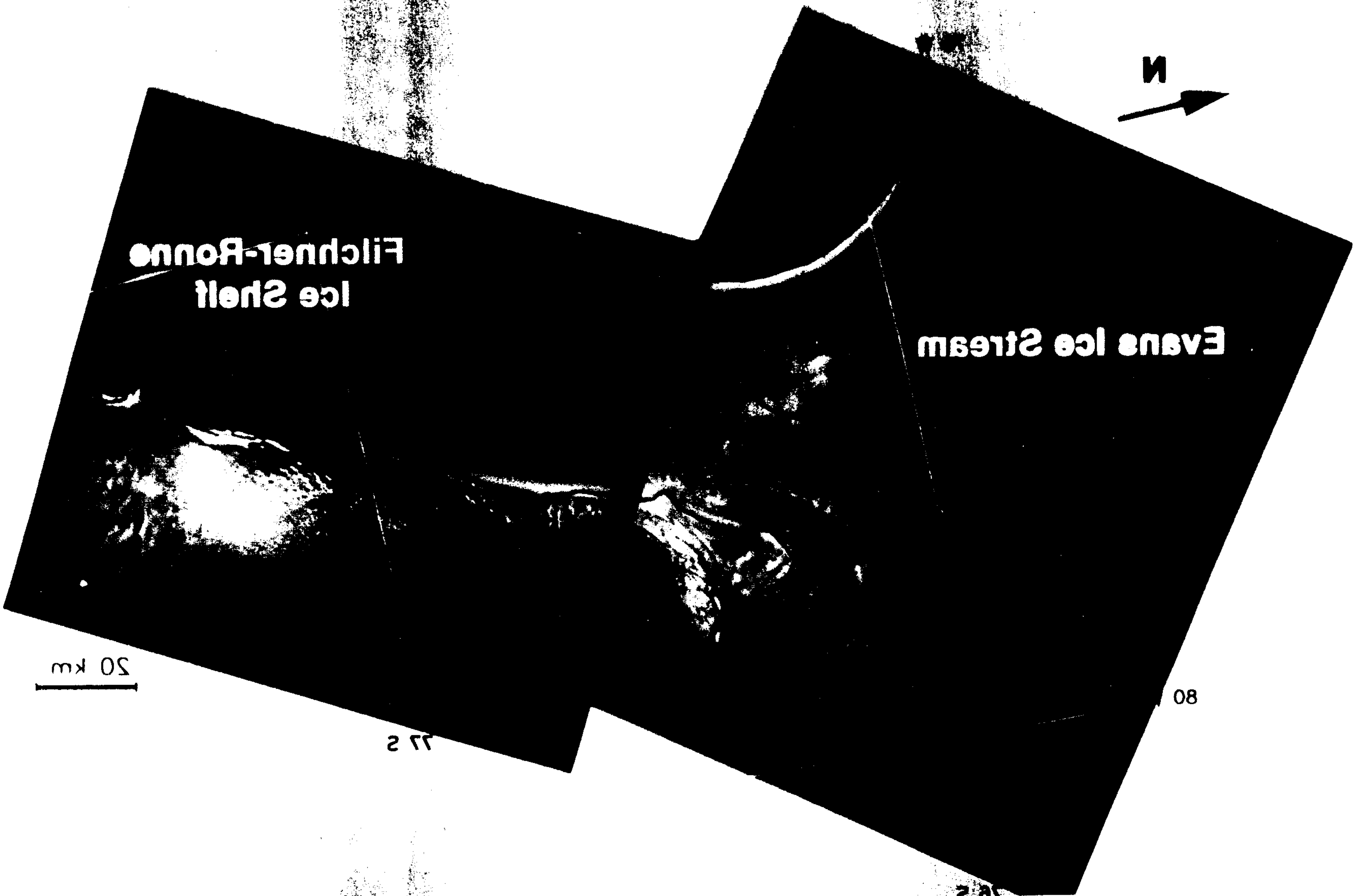
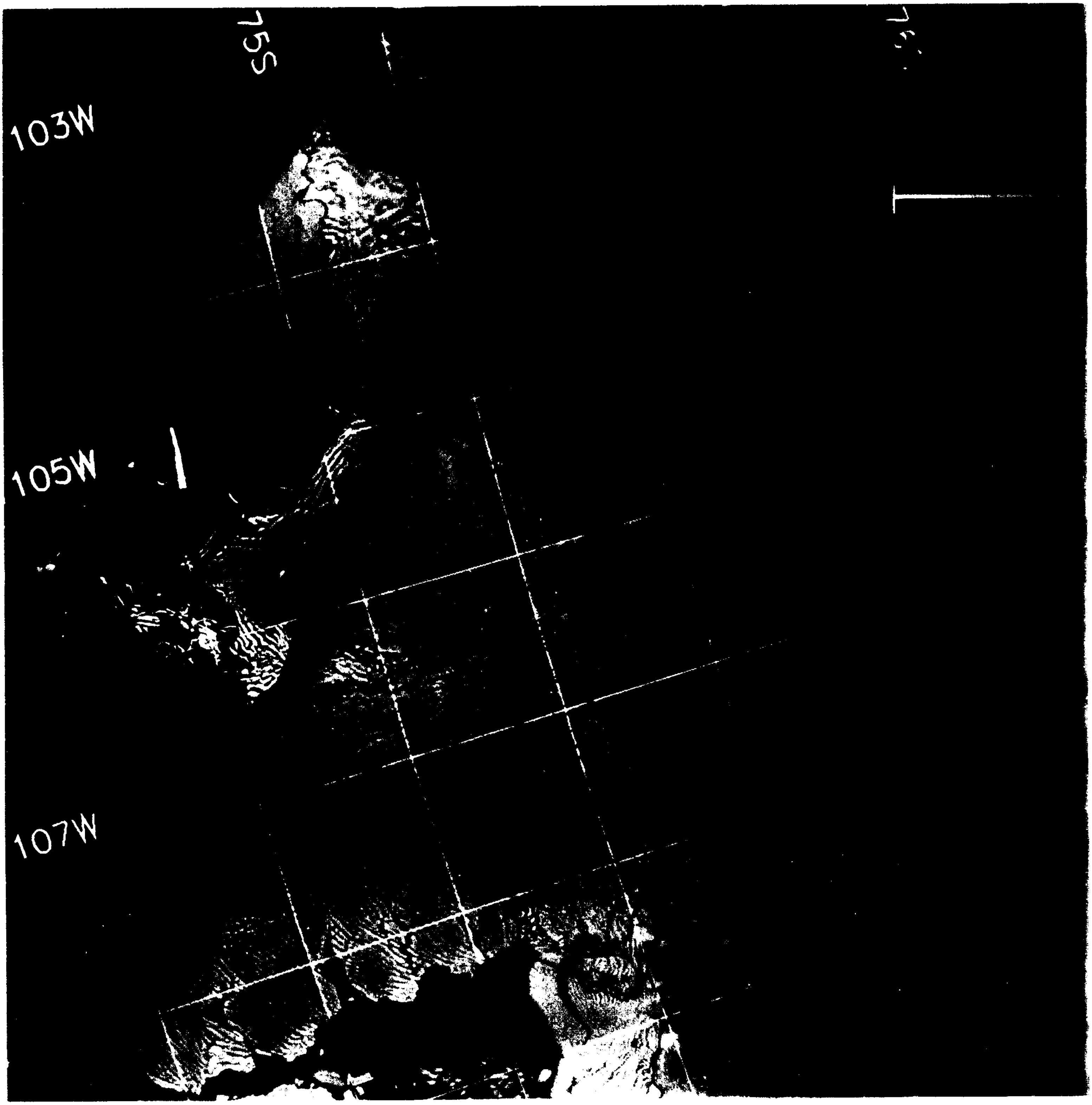
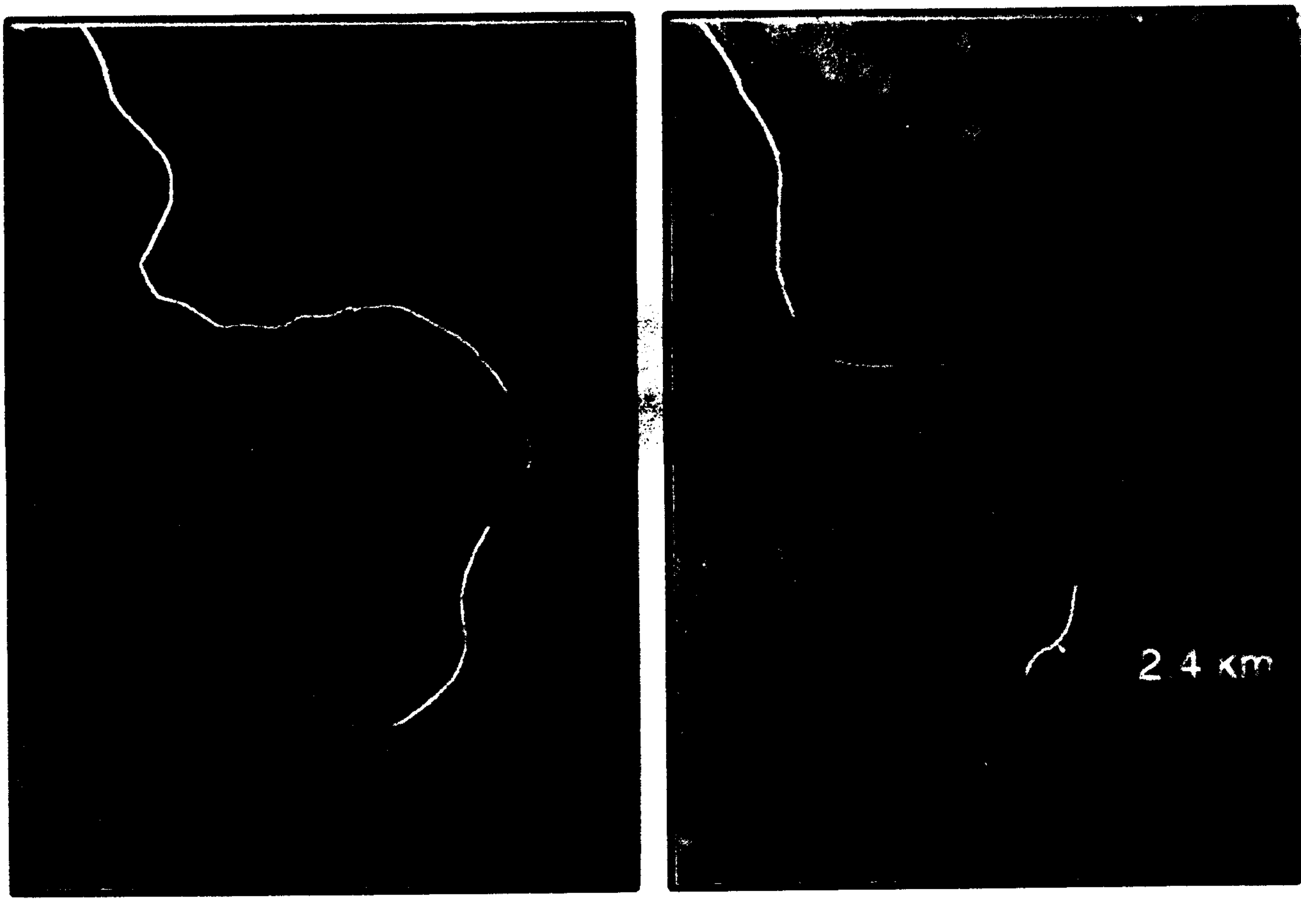


Filchner-Ronne Ice Shelf
Evans Ice Stream
N
20 km
77 S
76 S
80


75S
103W
105W
107W

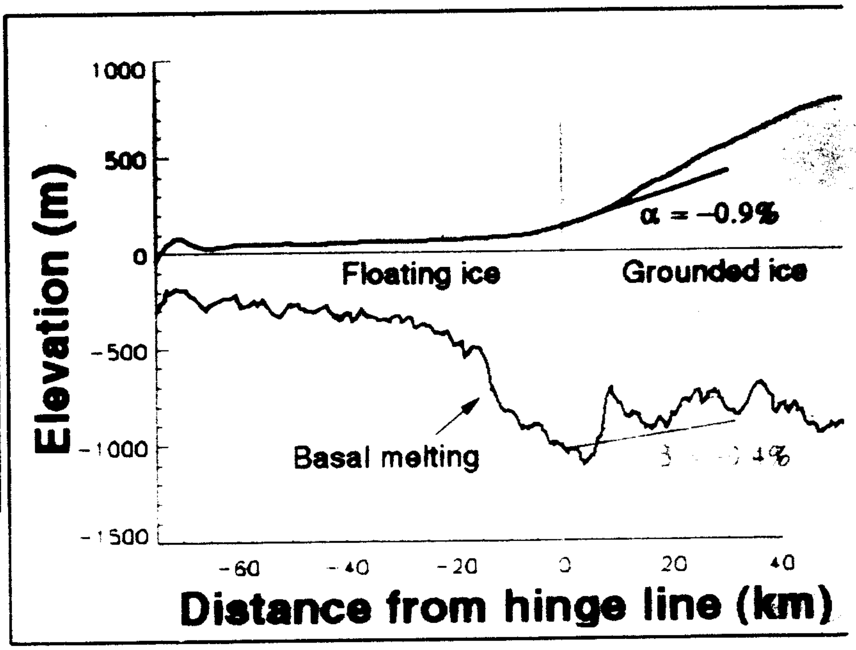
Grounding line retreat of Thwaites Glacier, Antarctica



$$\frac{\delta h}{\delta x} = \alpha - \beta \left(1 - \frac{\rho_w}{\rho_i}\right)$$

δx = 620±60 m/yr

δh = -3.1±.3 m/yr
(thinning)



Rignot, JPL 1999

CONCLUSIONS

• The mass budget method suggests that the ice streams controlling the discharge of West Antarctica into the Filchner-Ronne Ice Shelf are close to a state of mass balance, whereas the ice streams flowing into the Amundsen sea exhibit a negative mass balance.

• Glaciers draining East Antarctica are closer to a state of mass balance but the uncertainty in the result is also larger. Lambert Glacier is close to a state of mass balance, not thickening.

• The grounding line of Pine Island Glacier and Thwaites Glacier is retreating rapidly. The corresponding ice thinning rate of 3 m /yr at the grounding line is too large to be accommodated by changes in ablation and/or accumulation.

• Thwaites and Pine Island glaciers are undergoing a downdraw of their drainage basin, as suggested by Hughes. The glacial retreat is driven by enhanced glacier velocities most likely caused by enhanced sliding at the bed. The causes of enhanced sliding are unknown (removal of buttressing ice shelves, internal ice sheet dynamics, long-term signal from LGM, other).

• Although major advances will result from the complete analysis of ERS data, parts of East Antarctica are poorly covered, topographic mapping needs to be improved, and direct measurements of ice thickness would be preferable to proxy estimates.